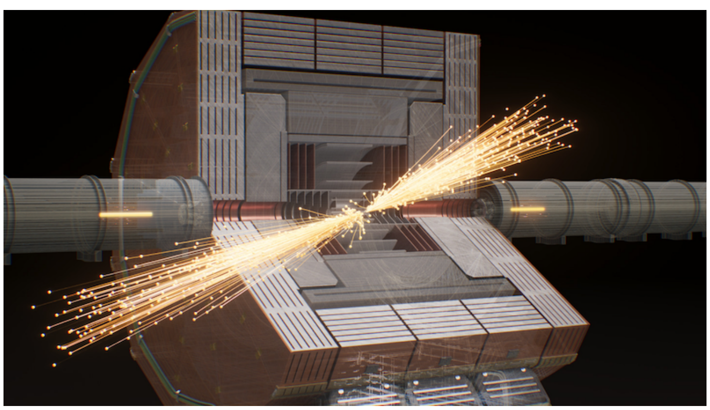
Collimating Positrons with Superconducting Magnets

A recent experiment points the way toward making the intense, energetic beams of positrons needed for next-generation electron–positron colliders.

By **Sam Jarman**

Future generations of particle colliders will demand abundant sources of positrons—the antimatter partners of electrons. The usual method for producing them involves smashing electrons into a target and corralling the outgoing positrons with magnets, but in its current form, this approach doesn't come close to meeting the demands of future experiments. Researchers at the Paul Scherrer Institute (PSI) in Switzerland have now made an important advance in positron production with a magnet design that uses high-temperature superconductors. Their preliminary measurements, announced in a press release, show that this technology can be scaled up to feed positrons to CERN's Future Circular Collider (FCC).

The FCC is a planned successor to CERN's Large Hadron Collider (LHC), which is expected to wind down its operations in the 2040s. Pending full funding for its construction, the next-generation facility will surpass the 27-km circumference of the LHC, reaching 91 km. Since charged particles emit energy-draining radiation when they follow curved trajectories, the lower curvature of this new, larger facility will allow them to reach far higher energies before colliding.



An artist's conception of a detector harvesting electron–positron collisions in CERN's Future Circular Collider.
Credit: Polar Media

Housed in a tunnel 200 m beneath the Franco–Swiss border, the FCC could potentially host several types of collisions; however, in May 2026, the CERN Council recommended electron–positron collisions as the long-term priority for the FCC, a strategy dubbed FCC-ee [**1**]. By smashing together electrons and positrons at much higher luminosities than previous lepton colliders, FCC-ee could enable unprecedentedly precise tests of the standard model of particle physics. In particular, it could run as a "Higgs factory," providing an abundant source of Higgs bosons to help physicists answer questions about the particle that have remained unresolved since its discovery at the LHC in 2012.

But before the project can enter the planning stages, it faces an immediate technological hurdle. "The FCC-ee needs a much larger number of positrons than current technology can efficiently produce and capture," says Paolo Craievich of the PSI Center for Accelerator Science and Engineering.

In existing positron sources like Japan's SuperKEKB collider, an electron beam is fired at a tungsten target, producing a shower of positrons traveling in many different directions. To focus the shower into a beam, the target is surrounded by a magnetic solenoid, which collimates the stray positrons using an intense field.

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"The real challenge for a positron source is not only to produce enough positrons but also to capture enough of them," explains Iryna Chaikovska of the University of Paris-Saclay, who wasn't involved in PSI's latest announcement.

In SuperKEKB, one of the highest-performing positron sources in operation, the capture magnet reaches field strengths of up to 3.5 tesla (T), which is not strong enough to meet the needs of the FCC-ee. The PSI Positron Production (P^3) experiment was set up to meet that demand. In a 2024 study, Nicolas Vallis and colleagues at PSI described a solenoid for the P^3 experiment designed to reach a peak field of 12.7 T on axis at the target [**2**].

To capture more of the stray positrons, Vallis' team needed a stronger magnetic field than conventional low-temperature superconducting magnets can sustain. Their solution was to fabricate a solenoid from coils of superconducting tape made from rare-earth barium copper oxide, or ReBCO. This family of compounds can superconduct at temperatures below 93 K, which is among the highest critical temperatures found so far. ReBCO is used for current-carrying leads in LHC's cooling system but not for electromagnets that steer and focus beams.

The researchers designed their coil to run far below this threshold, at 15 K. While this was still much warmer than the few-kelvin operating temperatures required by conventional superconductors, operating this far below ReBCO's critical temperature significantly boosted the current that the tape could carry. It also reduced the risk that thermal perturbations destroy the superconducting state. What's more, ReBCO's superconductivity survives even at high magnetic fields, a crucial property for a powerful solenoid. In 2025, the P^3 capture solenoid team, headed by Michal Duda of PSI, took a prototype of their solenoid to SwissFEL—PSI's x-ray free-electron laser facility.

Building on this achievement, PSI has now used the completed P^3 system to produce its first positron beam. After capture by the ReBCO solenoid, the positrons pass through a pair of radio-frequency cavities, which use oscillating electric fields to accelerate the particles and organize them into tight, stable bunches. The result is an efficiently generated positron beam, ready in principle to be injected into a circular accelerator. "Producing the first positrons successfully shows that all these technologies can work together," Craievich says.

There is still a long way to go before the technology can produce positron beams at the intensity, 10^{13} positrons per second, that will eventually be demanded by the FCC-ee. "These first results therefore provide important experimental validation of the baseline approach and its potential to achieve the required capture efficiency," Chaikovska comments. "An important next step will be to benchmark the measurements in detail and to demonstrate how this promising approach can be further optimized and scaled toward the full FCC-ee requirements."

Samuel Jarman is a science writer based in the UK.

REFERENCES

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2. N. Vallis *et al.*, "Proof-of-principle e^+ source for future colliders," **Phys. Rev. Accel. Beams 27, 013401 (2024).**